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**IMPROVING THE DISCIPLINE OF
COST ESTIMATION AND ANALYSIS**

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IMPROVING THE DISCIPLINE OF COST ESTIMATION AND ANALYSIS

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ABSTRACT

The need to improve the quality and accuracy of cost estimates of proposed new aerospace systems has been widely recognized. The industry has done the best job of maintaining related capability with improvements in estimation methods and giving appropriate priority to the hiring and training of qualified analysts. Some parts of Government, and National Aeronautics and Space Administration (NASA) in particular, continue to need major improvements in this area. Recently, NASA recognized that its cost estimation and analysis capabilities had eroded to the point that the ability to provide timely, reliable estimates was impacting the confidence in planning many program activities. As a result, this year the Agency established a lead role for cost estimation and analysis. The Independent Program Assessment Office located at the Langley Research Center was given this responsibility.

This paper presents the plans for the newly established role. Described is how the Independent Program Assessment Office, working with all NASA Centers, NASA Headquarters, other Government agencies, and industry, is focused on creating cost estimation and analysis as a professional discipline that will be recognized equally with the technical disciplines needed to design new space and aeronautics activities. Investments

in selected, new analysis tools, creating advanced training opportunities for analysts, and developing career paths for future analysts engaged in the discipline are all elements of the plan. Plans also include increasing the human resources available to conduct independent cost analysis of Agency programs during their formulation, to improve near-term capability to conduct economic cost-benefit assessments, to support NASA management's decision process, and to provide cost analysis results emphasizing "full-cost" and "full-life cycle" considerations.

The Agency cost analysis improvement plan has been approved for implementation starting this calendar year. Adequate financial and human resources are being made available to accomplish the goals of this important effort, and all indications are that NASA's cost estimation and analysis core competencies will be substantially improved within the foreseeable future.

INTRODUCTION

Everyone knows that the enemy of approval and startup of new programs is the cost analyst who has accurate estimation tools and a desire to deliver an honest estimate of what the program will really cost. The estimator is the person who develops program costs that exceeds budget availability, makes the

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program less competitive with other programs competing for limited resources, and often forces the program to focus on objectives somewhat less than desirable. Right? No, that is not exactly the way good management is supposed to work. A responsible program or project manager should consider a reliable cost estimate as a resource available for assuring management success.

Included in the primary reasons why many of today's aerospace program managers eventually find themselves in trouble are:

- 1) Before program approval, they may not have adequately defined (systems engineered) the system they planned to develop and operate. This includes developing a full understanding of technical and programmatic risks that can be barriers to success,

- 2) They may not have developed a reliable estimate of what it will cost to successfully complete the program, and

- 3) They may accept the job of managing the program with a budget (and maybe schedule) with little or no relation to the expected actual cost of the program.

So, what's so difficult? Why can't responsible program management correct these deficiencies and more often than not, deliver the program product within budget and on schedule? A primary requirement for success is the program manager wanting to be "responsible," and a second requirement is the program manager having the resources to complete quality, up-front systems engineering and to secure a reliable cost estimate.

This paper will not attempt to address the adequacy of systems engineering tools or other resources needed by the program manager. Much has been recently written about efforts to improve tools used in systems engineering, both in the United States and

other countries. Of particular interest is the Intelligent Synthesis Environment Program of NASA Langley (reported at last year's IAF Congress,)¹ with objectives to advance the state-of-the-art in near- and far-term analysis/design tools and promote collaborative engineering among engineering organizations. Providing reliable cost estimates (the focus of this paper) is a subject that has received less attention. Reliable cost estimation, as a resource to the program manager, has become a scarce commodity, at least in NASA. In addition, the image of the cost estimator, as the enemy to program approval, is wrong. Hopefully, what follows will show that NASA recognizes the value that reliable cost estimation brings to the program formulation and approval process.

Before turning to how NASA is correcting deficiencies in its program cost estimation capabilities, it may be helpful to define "cost estimation" as used in the following discussion. For the purpose of this definition, and for other discussions in this paper, "program" refers to an activity involving the development and operation of a hardware system, or more specifically perhaps, a space system. Cost estimation is the process of analyzing each hardware element, the buildup, integration and test of these elements, and the operation of the system over some specified life-cycle (including disposal of the asset), with respect to the cost associated with the total effort. The analysis uses analysis tools, or models, that relate hardware elements, complexity, and risks of failure to expected costs – a parametric analysis. Parametric estimation involves the development and utilization of cost estimation relationships between historical costs and program, physical, and performance characteristics. The basic premise is that the cost of a system, such as a spacecraft, is related in an approximate, but quantifiable way, to a physical characteristic

such as weight, pointing accuracy, number of parts, or other attribute.

There may be at least two different types of cost estimates, an "advocacy" estimate and an "independent" estimate. An advocacy estimate may be derived by program management, and as such, may be skewed in ways beneficial to successful program advocacy. An independent cost estimate is derived by one disassociated with the program, and therefore, not encumbered by the pressures of advocacy and free to be objective – "tell it like it is." Further, the cost estimation and analysis (CEA) competency is defined as the total capability of an organization to provide the cost estimates required by the organization for budget planning and execution, and program planning and approval.

BACKGROUND

NASA, at one time, maintained a respectable CEA competency. Qualified cost analysts were employed across the NASA Centers with appropriate skills and in numbers to support the Agency's needs. Several related situations resulted in the Agency losing much of its recognized competency:

1) The Agency never recognized CEA as a discipline as important as other professional disciplines needed for systems engineering and development. There was never a "career path" available to those responsible for CEA, so possibilities for career advancement were always in doubt. As a result, often other career opportunities looked more promising and qualified analysts left the work area.

2) Declining budgets, increasing competition for limited funds, and other institutional considerations, tended to lead many parts of the Agency to underestimate program development and operations costs. It

became obvious that estimators were too involved in the advocacy of the programs. The appearance of objectivity in the CEA process was in question.

3) Declining workforce led to the establishment of hiring priorities that limited the replenishment of CEA talent. In addition, limited budgets forced drastic reductions in investments that would lead to upgrading the Agency's CEA tools and state-of-the-art analysis capabilities.

In the early 1990s, several outside advisory groups began to recognize the declined state of the NASA CEA competency. Of particular importance was the Presidential Commission on the Future of Space², more commonly known as the Augustine Committee. The Commission recommended to NASA that "an exceptionally well-qualified, independent cost analysis group be attached to headquarters with ultimate responsibility for all top-level cost estimating, including cost estimates provided outside of NASA." As a complementary recommendation to foster the independent assessment of new proposed programs of NASA, the Commission also recommended the establishment of an independent "systems concept and analysis group reporting to the Administrator."

It was in the 1993 time period that the Agency formed a cost analysis group in the Headquarters Office of the Chief Financial Officer. This group was also given the responsibility to organize and conduct Independent Annual Reviews (IAR) of the progress of Agency programs and report findings to the Agency Program Management Council. This action recognized that independent cost analysis and the development of dependable estimates were of critical importance to NASA. About 4 years later, at the insistence of the NASA Advisory Committee, the Independent Program

Assessment Office (IPAO) was formed at the NASA Langley Research Center. The IPAO provides Independent Assessments (IA) of new programs, and reports findings and recommendations related to the approval of programs to the Office of the Administrator. The responsibility for the Independent Annual Reviews was transferred to the IPAO at that time. With the formation of the IPAO, the cost estimation function previously established all but disappeared, except for a small number of cost analysts that joined the IPAO at Langley to continue cost analysis to support the review and assessment activities.

During the period from the mid-1980s to the present, for the reasons stated earlier, there was a greater than 50 percent attrition in the NASA CEA competency. At present, the Agency of over 18,000 people employs less than 25 full-time, career cost analysts. In addition to the inability to develop sufficient cost information for management of its programs, there is concern for the Agency's ability to adhere to Federal standards in this area. The various remaining elements of the cost community are decentralized and have ambiguous roles and responsibilities. There is ineffective use and limited sharing of these resources, and there is no clear definition of a professional cost estimation competency.

The Agency currently conducts systems engineering, budget development, and cost estimating separately. There is inconsistent use of cost estimating techniques and tools, and there are outdated tools and cost databases. During program planning, program requirements and risks to program success are not adequately defined, and usually, no program life-cycle costs are considered in the approval process. Cost analysis tools are insufficient for estimating program cost for programs that are to be conducted with "new ways of doing business" or "faster, better, cheaper." And to add to

these deficiencies, budget-driven processes often are unsupported by CEA.

The Federal Office of Management and Budget (OMB) is pushing for improved cost analysis prior to budget submission. The OMB goals include better schedule and performance goals, more realistic baseline cost, the inclusion of independent cost estimates, and full life-cycle cost, cost benefit, and estimate of risk and uncertainty. All these cost considerations should be used as a basis for selecting future NASA programs.

Lastly, in recognition of the above deficiencies, the Administrator recently directed improvements in NASA's independent cost estimation abilities. His direction resulted in the assignment to the IPAO this year the Agency lead responsibility to correct the deficiencies and restore the Agency's cost estimation and analysis competency. The following discussion details the plans to fulfill the new IPAO role.

OVERALL STRATEGY

With the assignment of the lead role for cost estimation and analysis to the IPAO, the primary responsibility of the Office will be the reconstitution of a comprehensive, core CEA competency for the Agency. This responsibility includes the development of a CEA strategic plan for the accomplishment of the role, providing leadership for the establishment of an adequately staffed and skilled NASA cost estimating community, and rallying the community in a coordinated effort to eliminate the cost estimation deficiencies currently plaguing the Agency. The IPAO, NASA Headquarters, and the NASA Centers will work together toward implementation of state-of-the-art costing capabilities including investing in new and upgraded tools, and organizing appropriate training. The Office will function as an

independent Agency resource for program, Center, and Enterprise management by providing independent cost estimates to support program planning and implementation.

GOALS

The overall goal of the lead CEA activity is to prepare NASA for the future by restoring the ability to develop accurate, reliable cost estimates of the Agency's programs and provide confidence for senior leadership that NASA's programs are based on a solid foundation of understanding cost and risk. The new CEA core competency created will involve state-of-the-art business practices for a full spectrum of cost analysis tools and processes for managers and assure integration of cost estimating, systems engineering and management, and budget development. Cost estimates will be timely, and a better understanding of risk and schedule issues will be developed prior to program approval.

Specific examples of CEA competency improvement goals include making the following changes in the way NASA derives its program cost information:

1. Traditional, non-integrated tools will be replaced by state-of-the-art, integrated tools.
2. Center oriented cost organizations will become part of an intra-Agency cost community.
3. Functionally focused cost tasks will transition to integrated product teams that include estimating professionals.
4. Non-professional "journeymen" cost analysts will be trained and matured into core competency cost analysts.
5. Non-full cost estimates will be substituted with full cost estimates.
6. Center oriented tools will become shared Agency tools.

7. Separate development and operational costs estimates will be replaced by integrated, full life-cycle estimates.

The focus of the CEA improvement initiative will be on people, tools, organization, and processes.

PEOPLE

The most important resources in any activity are the people involved. For success, the people must be competent, motivated, and have the other resources (tools, money, etc.) to get the job done. As stated earlier, NASA is short of properly skilled cost analysis workforce. Therefore, attention to the "people" factor becomes a first-order priority of the NASA CEA improvement initiative.

Adequate compensation is a genuine motivator, but it is well known that when one decides to work in the public sector, there are limits to what one can expect in terms of pay. Therefore, there must be other motivators that cause an employee to want to make a career in government. With respect to those working in the CEA field, for example, expectations of being treated as a valued employee with definite opportunities for professional growth is a true plus. Unfortunately, in NASA, there has not existed much of a professional career path. In fact, while systems development activities require a wide variety of professional disciplines to implement the program, the activities also require CEA, but CEA is not viewed as a discipline in the same way as other areas (such as the engineering disciplines). A primary goal of the initiative is help establish CEA as a recognized professional discipline with a formal growth ladder and opportunities for senior level positions for individuals dedicated to the area. The IPAO will work

with NASA's human resource organizations to help develop this potential.

The IPAO will assist the NASA Centers in recruiting new employees to the Agency's core competency of CEA. A database of qualified individuals with interest in working for NASA in this area will be maintained, and as a Center wishes to supplement or replenish its CEA staff, the Office will offer appropriate assistance in seeking qualified applicants. The Office will also work with the Agency's career training organizations to help develop CEA-related training opportunities for the staff. This should include various professional and leadership training as well as specific training in the CEA discipline to improve the individual's skills. In addition, the IPAO will help develop Agency-wide on-the-job training that will improve professional development while creating opportunities for inter-Center exposure and cross-fertilization of CEA methods among Centers.

Lastly, the IPAO will invest in the development of a college undergraduate course on CEA. It is interesting that in an environment of economic pressure, constant push to reduce cost, and to build systems "faster, better, and cheaper," we graduate engineers without a notion of how much it costs to build the systems they are trained to design. The course will be designed with the objective of introducing college engineering students to cost analysis, and will be offered to any engineering school desiring to improve its engineering curriculum in this regard. If an appropriate one can not be found, there is some thought currently being given to the development of an undergraduate-level text on the subject of CEA for the purpose of aiding in the teaching of the course.

TOOLS

NASA must be capable of generating responsive, reliable, quality cost estimates of future missions (such as Mars Exploration) that involve the use of new technologies and innovative approaches or concepts for satisfying mission objectives. In order to achieve this capability, the IPAO will be responsible for advancing the state-of-the-art in cost models and analytical tools. One of the first capabilities identified for immediate development is the integration of systems development cost models with operations cost models. Efforts are underway to integrate the Space Operations Cost Model (SOCM)³, which is an internally developed model, with several commercial models such as the NASA/Air Force Cost Model (NAFCOM) and the PRICE Cost Model.

There are on-going discussions within the CEA community about the requirements of the next generation of NASA cost models. In the near future, NASA management will require "full cost" estimates, estimates that include the workforce, general & administrative costs, facility, and program/project costs. Models to estimate workforce cost are being developed to meet this requirement along with other methodologies to estimate the full cost of NASA projects. The NASA Integrated Financial Management System, currently being developed elsewhere in NASA, will assist in providing the CEA discipline with the full cost accounting data needed to develop full cost estimates. Also, models will be required to more accurately determine the cost impact of new systems development approaches such as "faster, better, cheaper."

The Intelligent Synthesis Environment (ISE) program is a NASA initiative to develop a virtual reality design environment. The goal is an advancement of the simulation

based design environment involving the integration of design and cost models with analytical tools using intelligent systems technology. As a result of this new environment, the time to develop new system designs and to estimate the costs will be greatly reduced. IPAO will be collaborating with the ISE program, specifically with the Cost and Risk Management Technology element of ISE, to develop cost and risk models that work within the ISE environment. These cost models must be capable of reflecting the revolutionary reduction in the time and cost of various phases of the design cycle and be state-of-the-art tools. Among the analytical tools planned for development is an improved schedule assessment tool.

IPAO will lead NASA's participation in the establishment of joint tool development efforts with other government and private industry cost analysis organizations. Recently, NASA became a member of the newly established Consortium on Space Technology Estimating Research (CoSTER) organization. The CoSTER includes most of the government agencies with an interest in space. This relationship will likely result in joint tool development investments that will benefit a broader range of government organizations. In addition, there will be efforts to assure cost model training opportunities are made available to all cost analysts. The result of CEA tool investments will be powerful cost-, schedule-, and risk-estimating systems that help NASA better understand the cost of doing business and make the right management decisions.

ORGANIZATION

The IPAO will carry out its CEA responsibilities with active participation of all NASA Centers and Headquarters. The Agency-wide initiative includes the creation of a CEA Steering Group with members

representing all the cost estimation organizations across NASA. This group is actively involved in establishing overall goals of the initiative, in decisions affecting the future of the CEA competency, in defining workforce and analysis tool requirements, and in the implementation of the initiative's elements. Group members represent the CEA-related interests of their home Centers, serve to share experiences (or lessons-learned) from cost analysis activities, and accept complementary responsibilities for various initiative actions. In addition, the group will facilitate an Agency-oriented CEA culture rather than a specific Center-oriented culture.

The IPAO, in cooperation with the CEA Steering Group, is organized to serve the Agency in several important ways. It is a primary interface with other government agencies to coordinate inter-Agency CEA activities, perform completely independent, non-advocate cost estimates in support of program formulation, and provide other CEA support to Centers when Center resources are insufficient. For the CEA initiative, the IPAO workforce was increased by eight, and sufficient funds have been provided to secure contracted CEA analysis to meet support demands. In addition to the IPAO, it is expected that the Centers' CEA organizations will also be appropriately expanded to meet the cost analysis requirements unique to each Center.

The IPAO CEA responsibilities include serving as the voice of the Agency's cost estimation and analysis community. The Office will integrate the fragmented concerns of 10 NASA Centers into focused CEA community concerns and issues, and this consolidation will enable the community's voice to be much stronger than each Center acting separately. It is expected that this will result in more positive results in efforts to

resolve the overall CEA competency deficiencies.

PROCESSES

Since one of the responsibilities of the IPAO in the CEA initiative is to oversee the quality control of the Agency's CEA products, the Office will be working to create standards for the discipline and to have all Center "buy-in" to the standards. The main focus on creating standards will be to ensure that CEA processes are consistent and conform to the best business practices, provide timely and accurate cost estimates, and are of maximum value to the Agency. The CEA Steering Group will lead in the development of the standards, and it is expected that all processes will be subject to ISO certification. Included in the processes will be guidelines for cost analysts' continued participation through the project's life and being involved in the creation of full-cost estimates of the system development, operation, and disposal. A closer relationship between those responsible for developing systems requirements and those responsible for estimating requirement's cost must be developed. The full integration of CEA into design activities is necessary. Cost analysts must be active participants in initial system trade studies that should be conducted to derive the system approach that achieves the requirements in the most cost-effective way. In today's program management world, the cost analyst must remain an active, but objective member of the team throughout the entire life-cycle of the program.

SUMMARY

The IPAO led CEA initiative will focus on up-front planning and continued improvement of the NASA CEA competency and will provide key benefits to the future

systems development activities of the Agency. These benefits include the following:

- 1) A new cost estimating culture and an integrated cost community that better serves the Agency.
- 2) Enhanced costing skill and a professional career path for analysts.
- 3) Better definition of systems development and operational risks and an estimate of the costs to mitigate these risks.
- 4) Reliable, responsive, full life-cycle cost estimates.
- 5) Cost estimate quality control.
- 6) Continual CEA support throughout project life-cycle.
- 7) Databases for improved cost estimating and cross program analysis.
- 8) State-of-the-art, user friendly tools and processes that accommodate NASA's new ways of conducting systems development activities.
- 9) Make the Agency more OMB-compliant.
- 10) Better fiscal support and budget defense

The IPAO, in its lead role for CEA, will function as an independent Agency-level resource and will ensure all Centers are involved in the reconstitution of this most important Agency discipline. The bottom line is that after these changes are instituted, both the Agency and those in charge of NASA's appropriations will have a much greater confidence that our proposed costs will also be our actual costs. This will make our budgets more defensible, leading to better Congressional support.

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